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(54) **PRINTING OR COATING APPARATUS AND METHOD**

(75) Inventors: **Marian Cofler**, Lod (IL); **Alex Veis**, Kadima (IL)

(73) Assignee: **Hewlett-Packard Development Company, L.P.**, Houston, TX (US)

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(22) Filed: **Feb. 13, 2009**

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(51) **Int. Cl.**

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B41J 3/28	(2006.01)
B41J 11/00	(2006.01)
B41J 13/00	(2006.01)

(52) **U.S. Cl.**

CPC ***B41J 3/28*** (2013.01); ***B41J 11/0015*** (2013.01); ***B41J 11/002*** (2013.01); ***B41J 13/0072*** (2013.01)

USPC **347/102**

(58) **Field of Classification Search**

USPC 347/102

See application file for complete search history.

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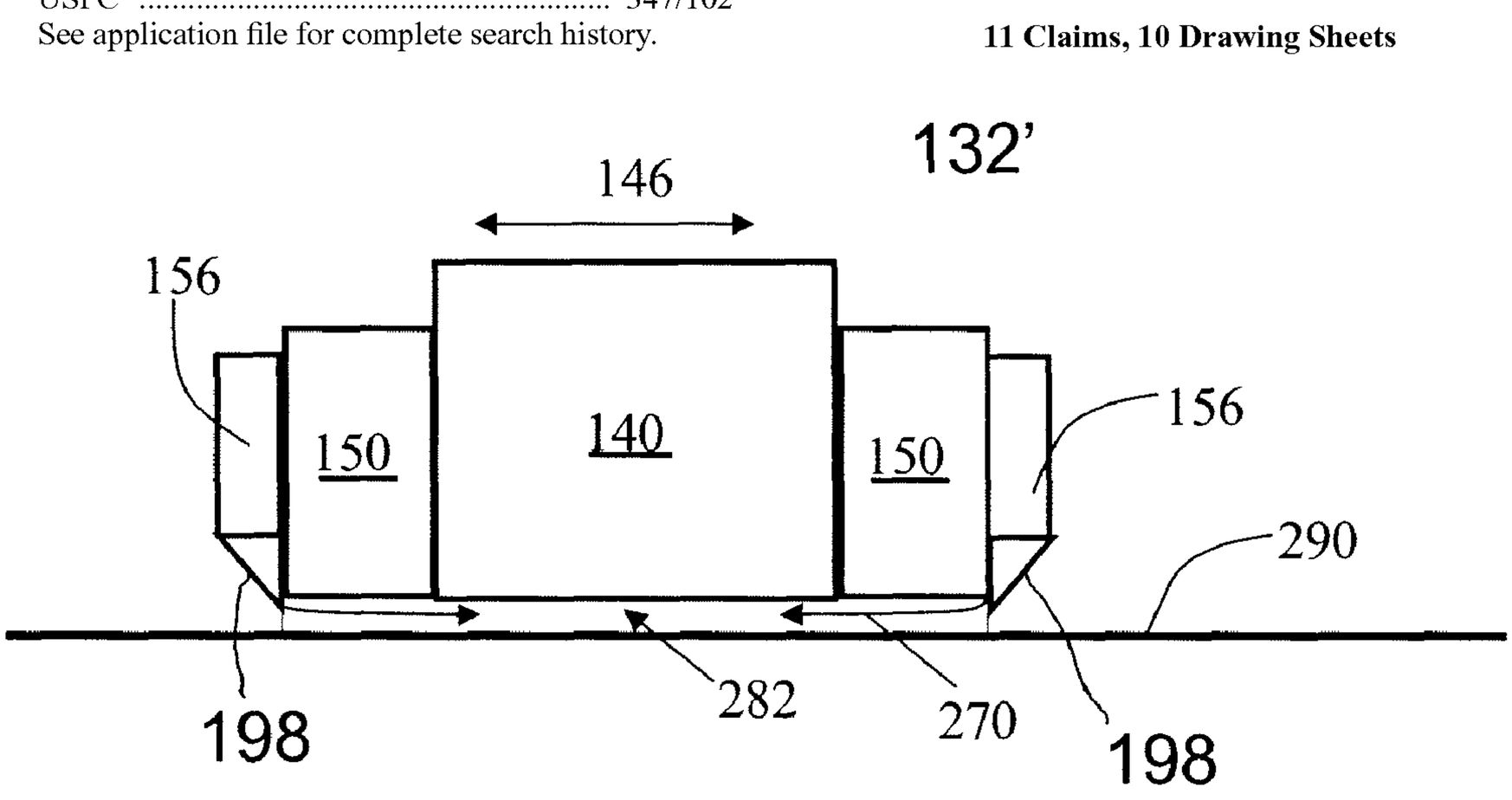
Primary Examiner — Alessandro Amari
Assistant Examiner — Jeremy Bishop

(57) **ABSTRACT**

An inkjet printing apparatus for printing on a substrate comprises a first support, which is a substrate support, and a second support which supports at least one inkjet printing head, at least one UV source of ultraviolet radiation, and at least one gas dispenser. The second support is moveable relative to a substrate supported by the first support. The printing head deposits ink on the substrate and the UV source cures the deposited ink. The gas dispenser is arranged to provide a layer of gas, which is at least depleted of oxygen, between the UV source and the substrate.

11 Claims, 10 Drawing Sheets



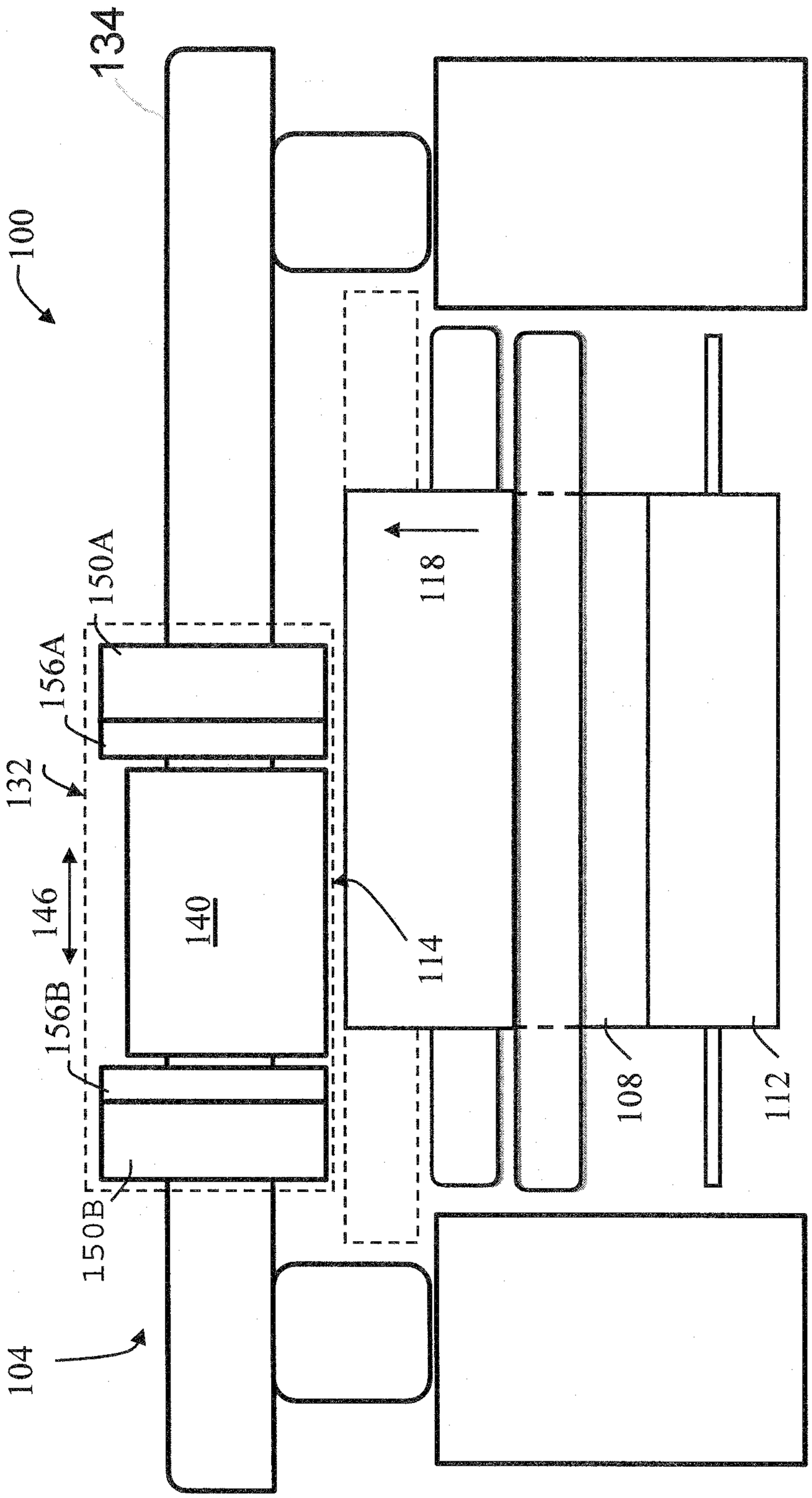


FIG. 1A

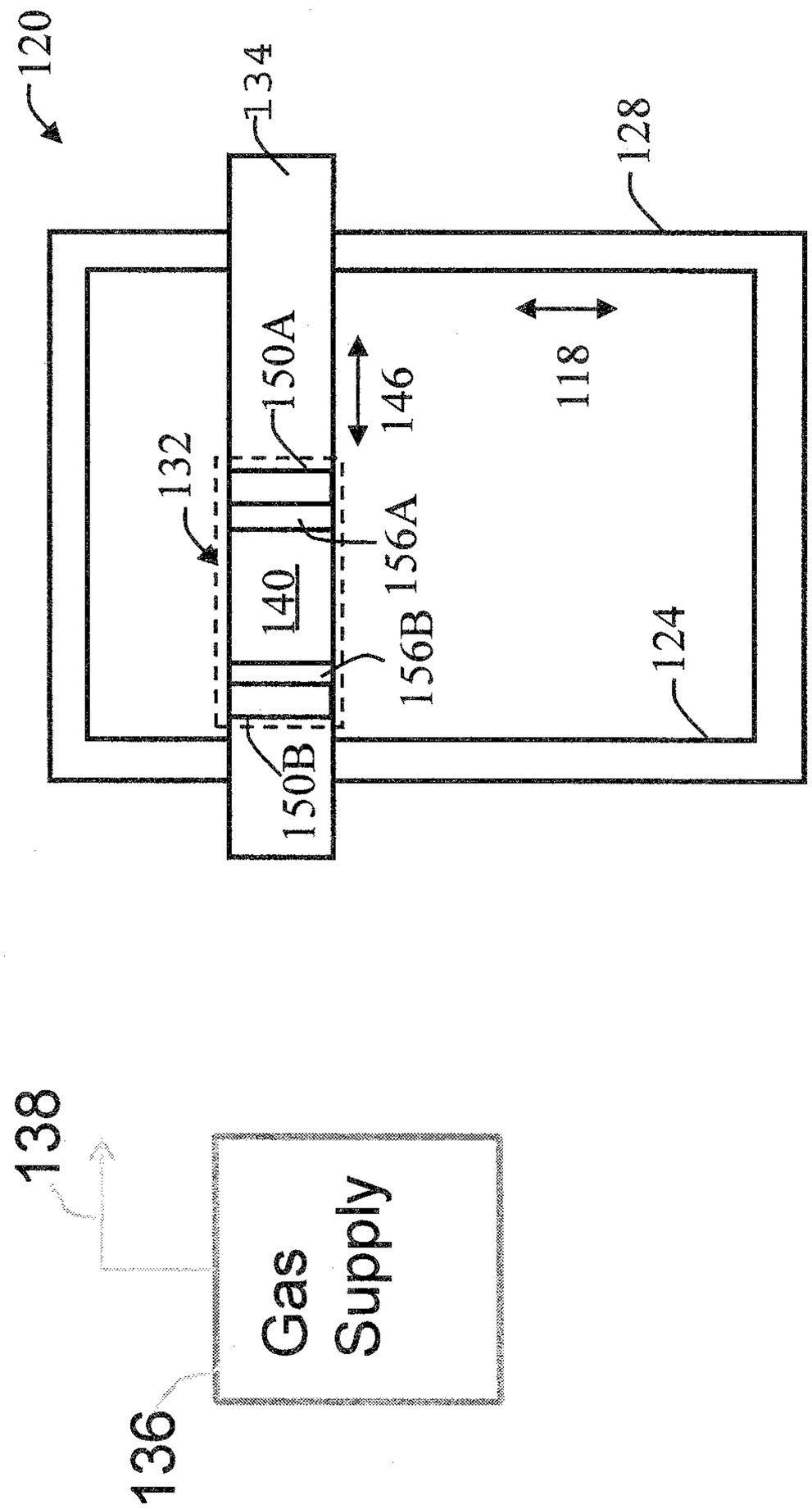

120
134
128
150A
146
118
132
140
156A
156B
124
150B
138
Gas Supply
136

FIG. 1B

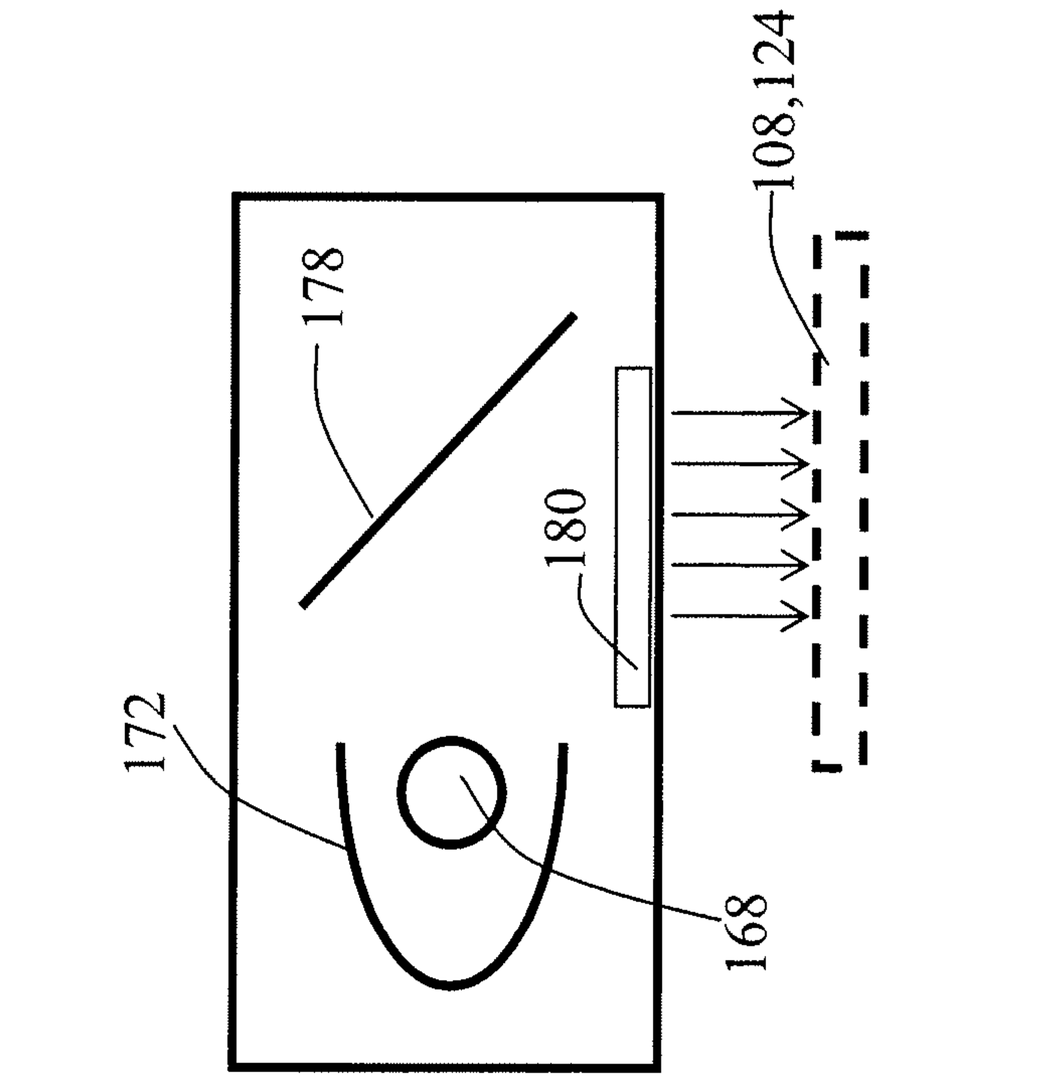


FIG. 2A

FIG. 2B

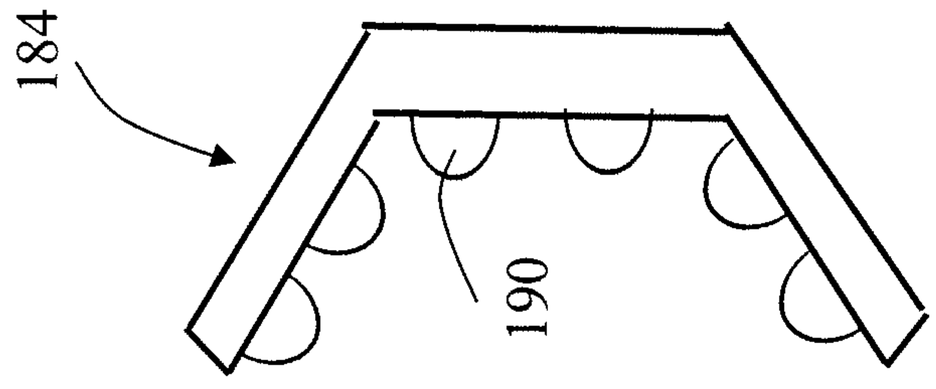


FIG. 3C

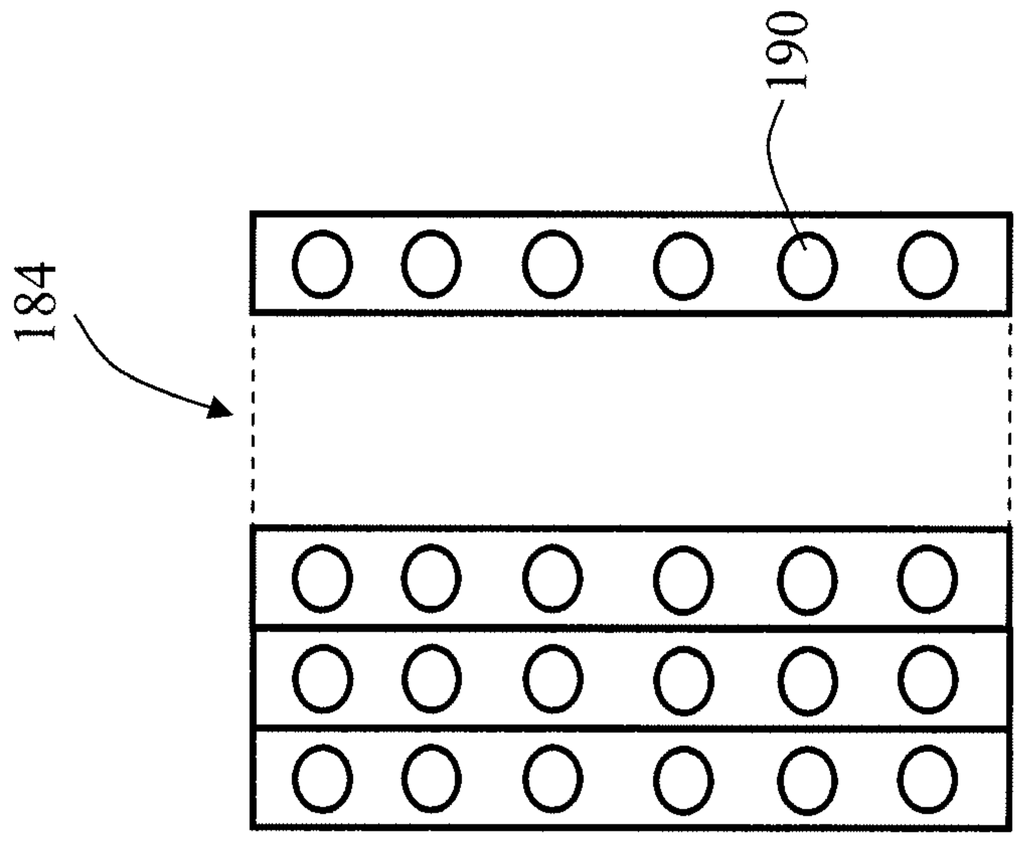


FIG. 3B

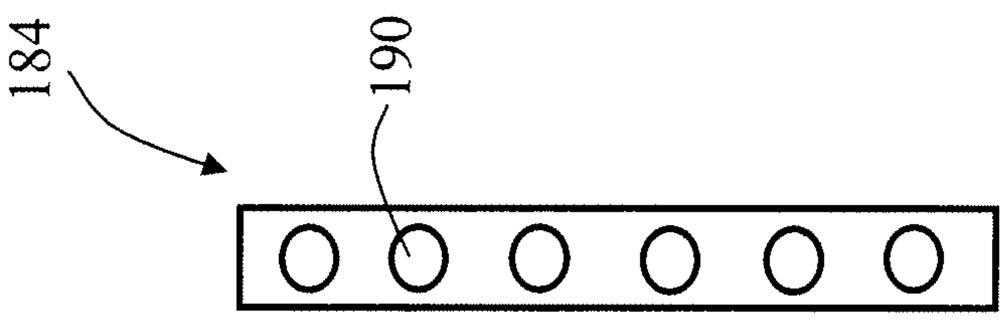


FIG. 3A

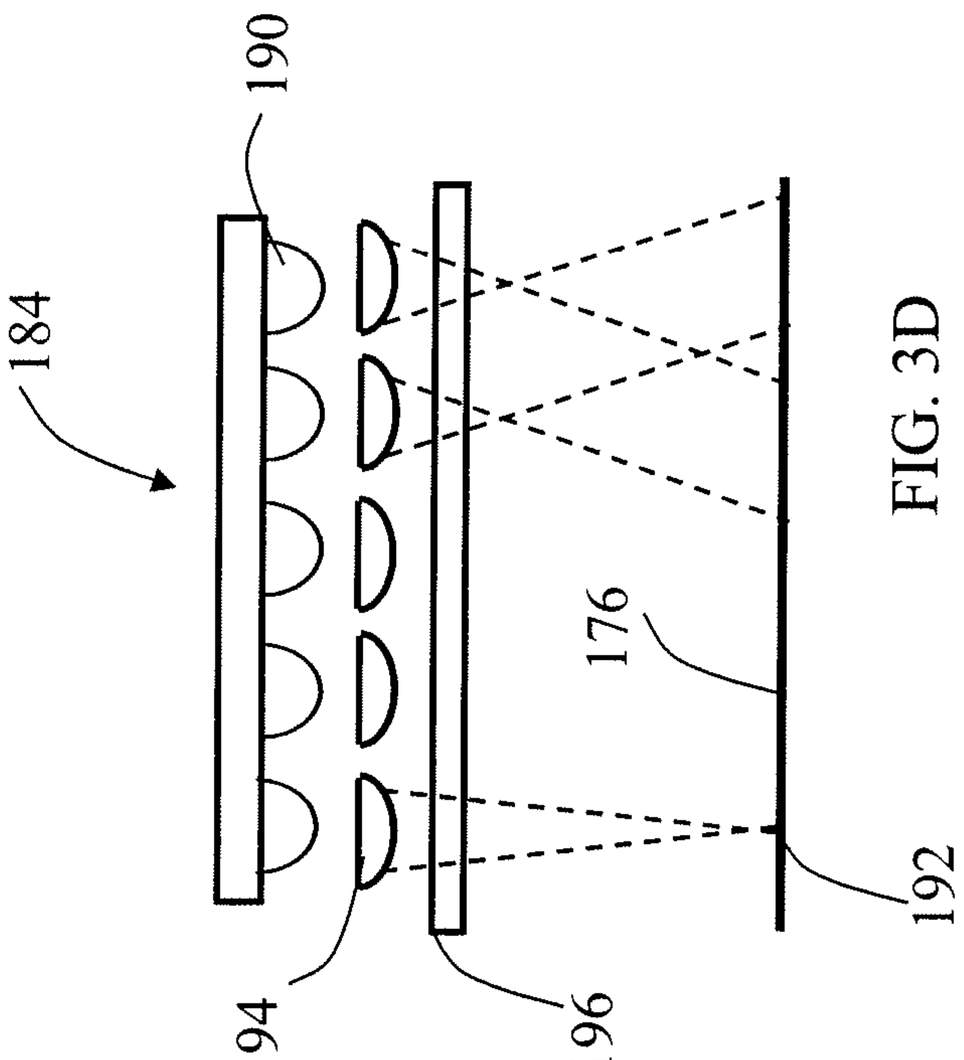


FIG. 3D

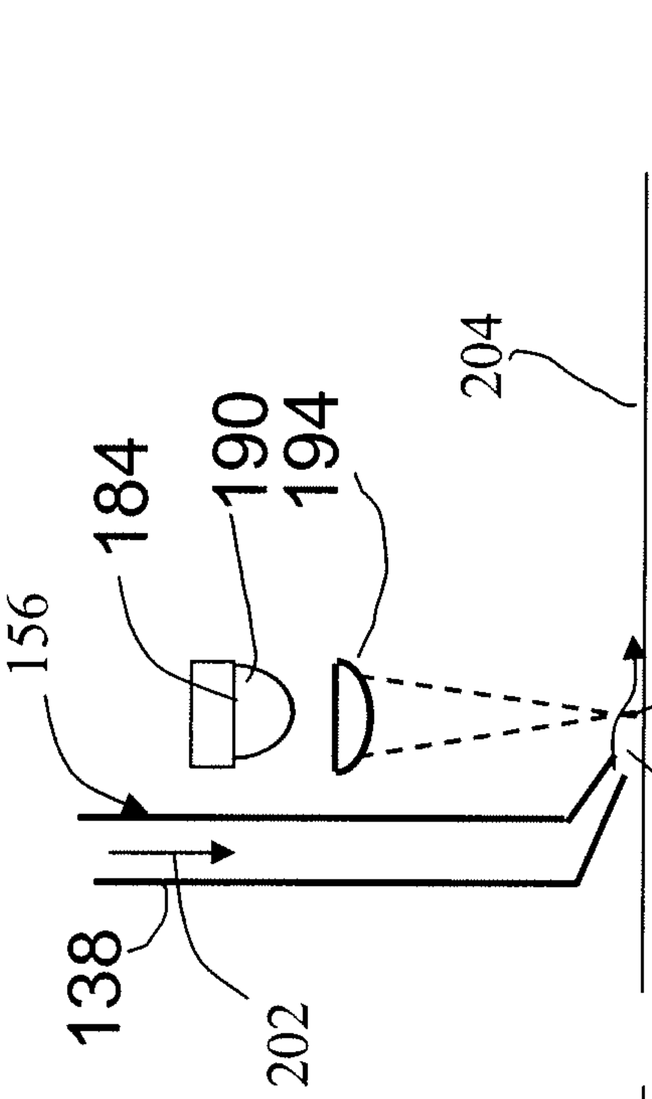


FIG. 4B1

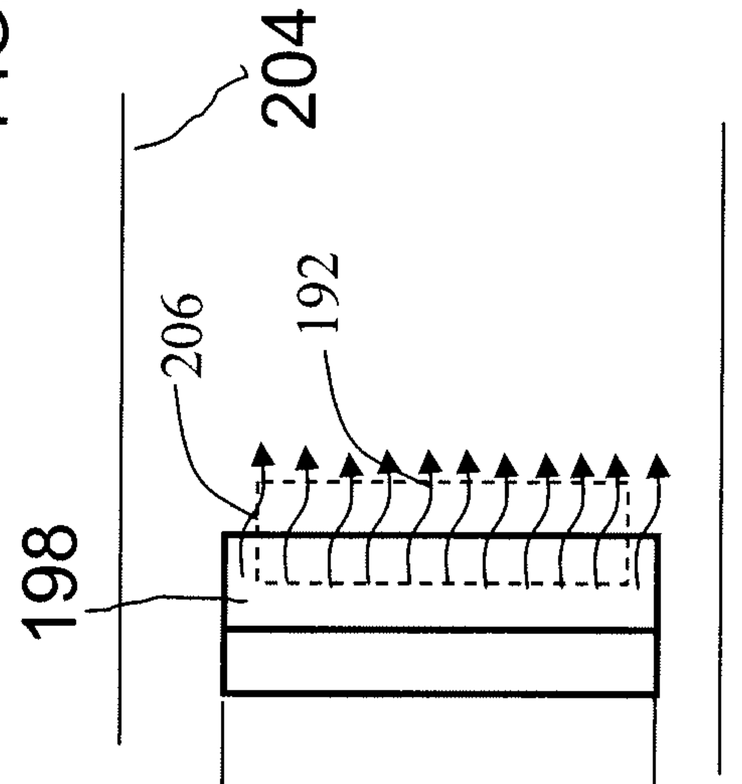


FIG. 4B2

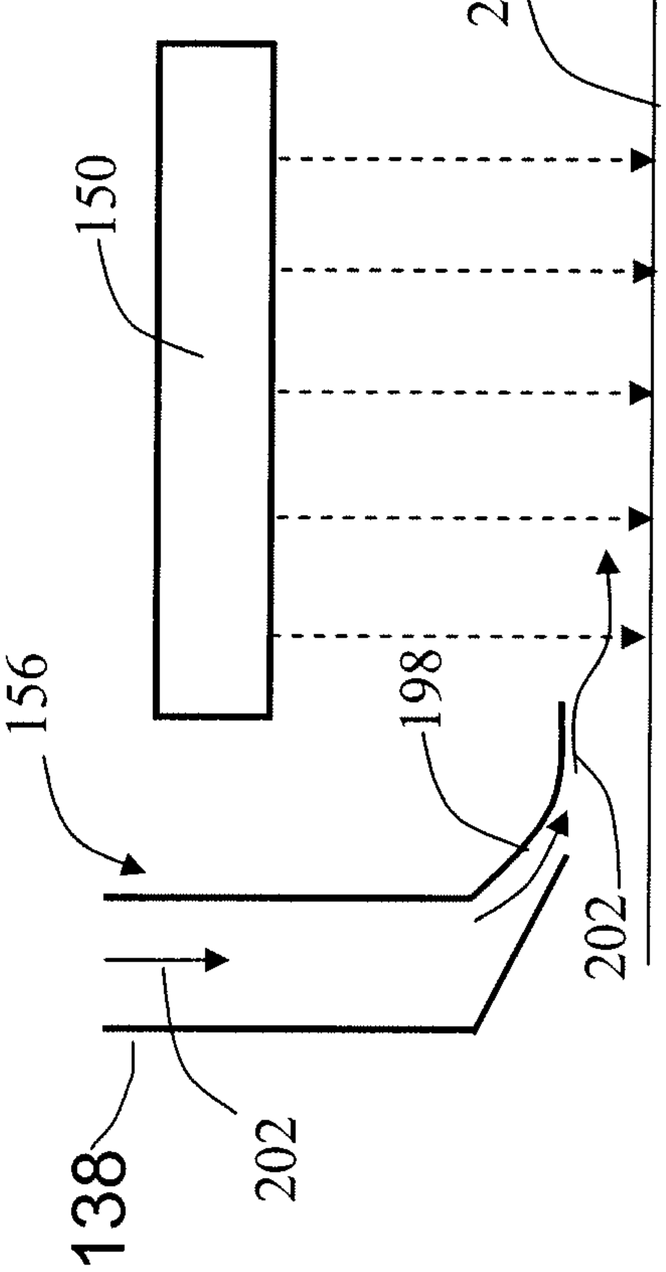


FIG. 4A1

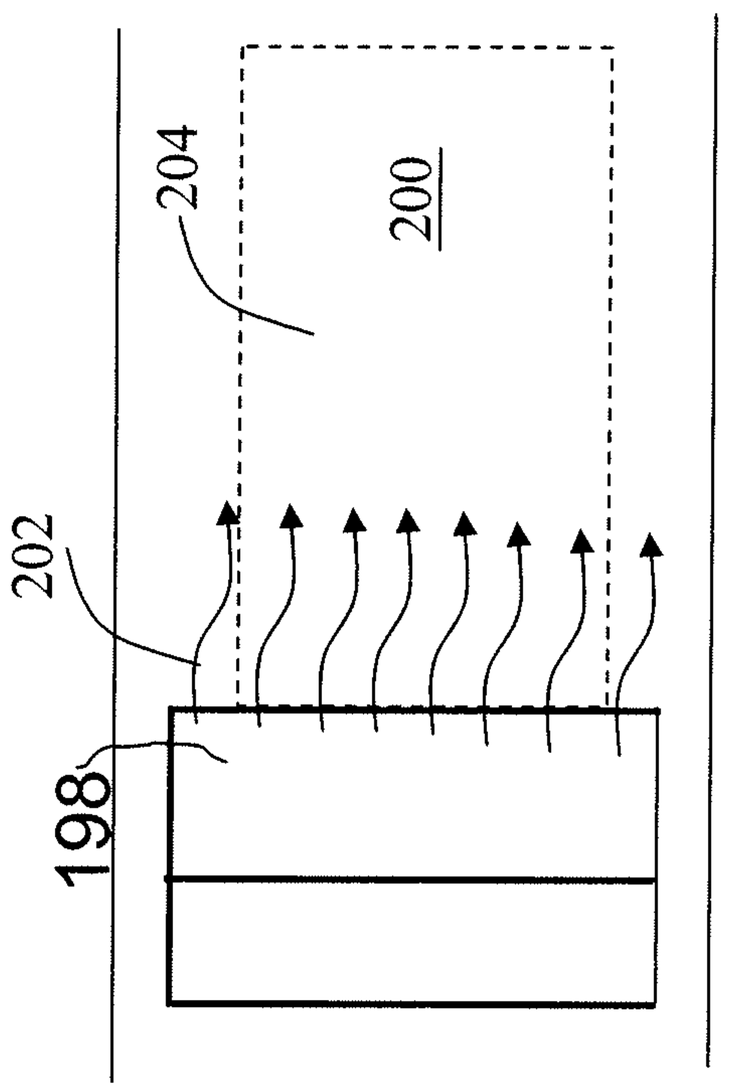


FIG. 4A2

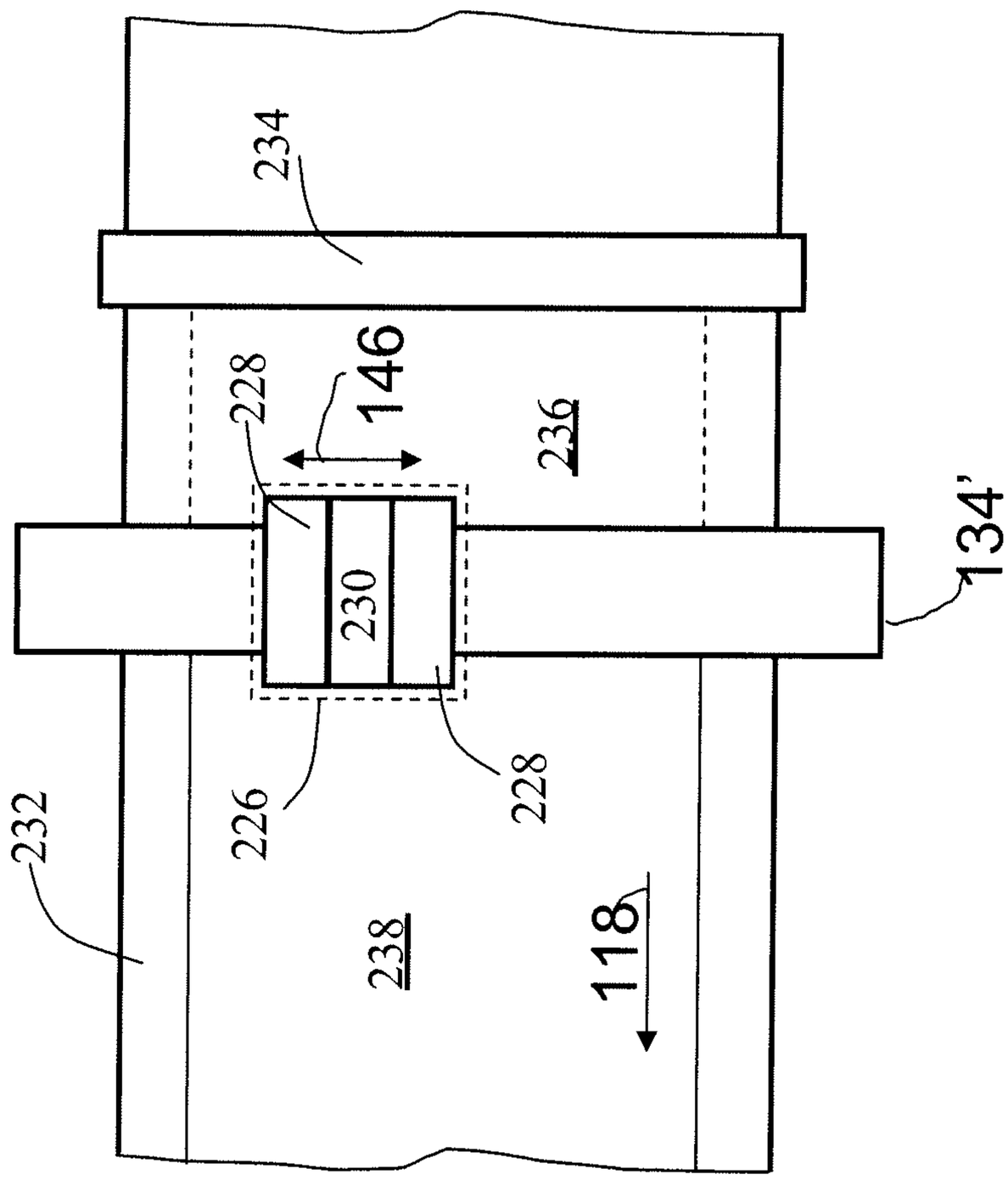


FIG. 5

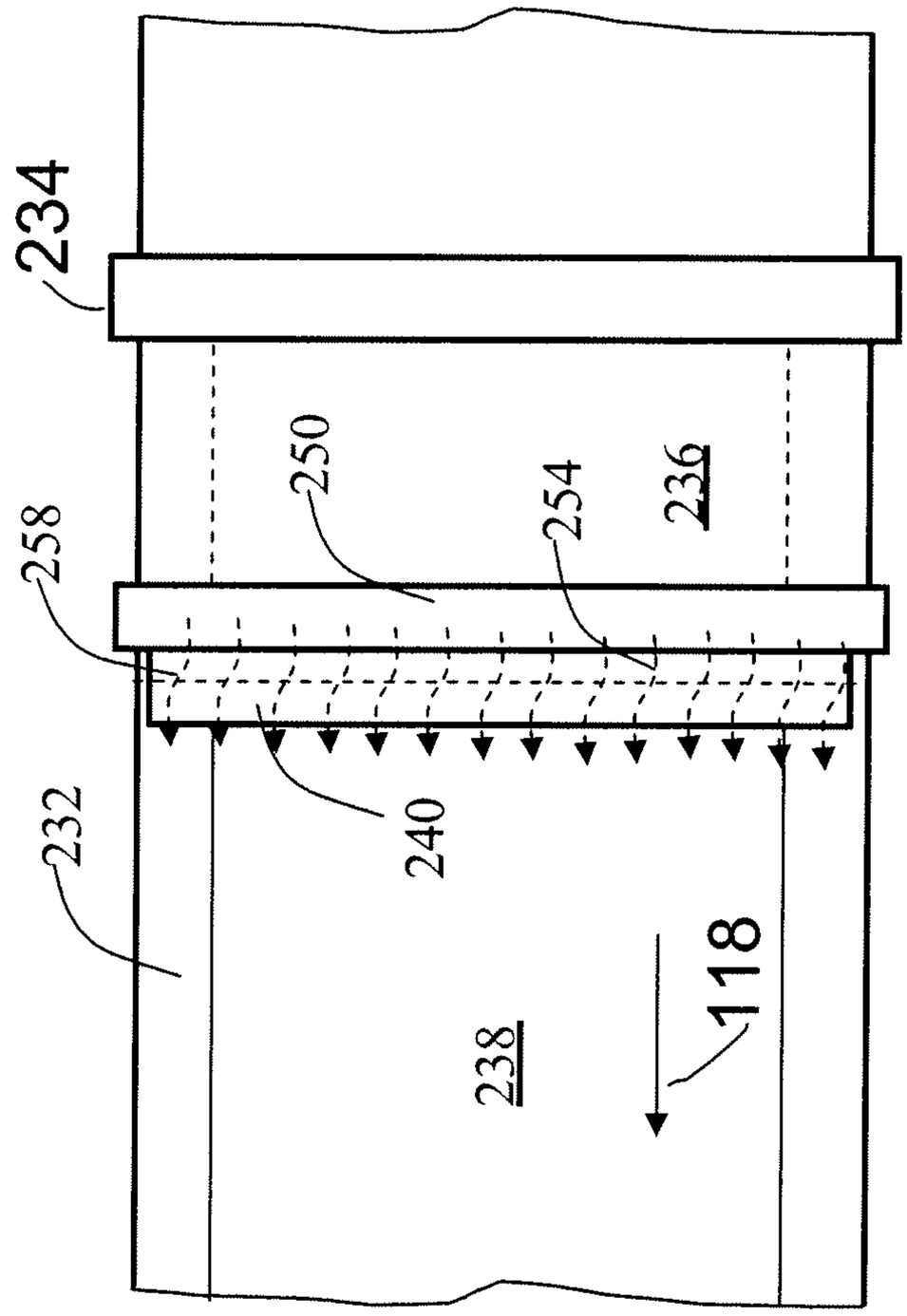


FIG. 6

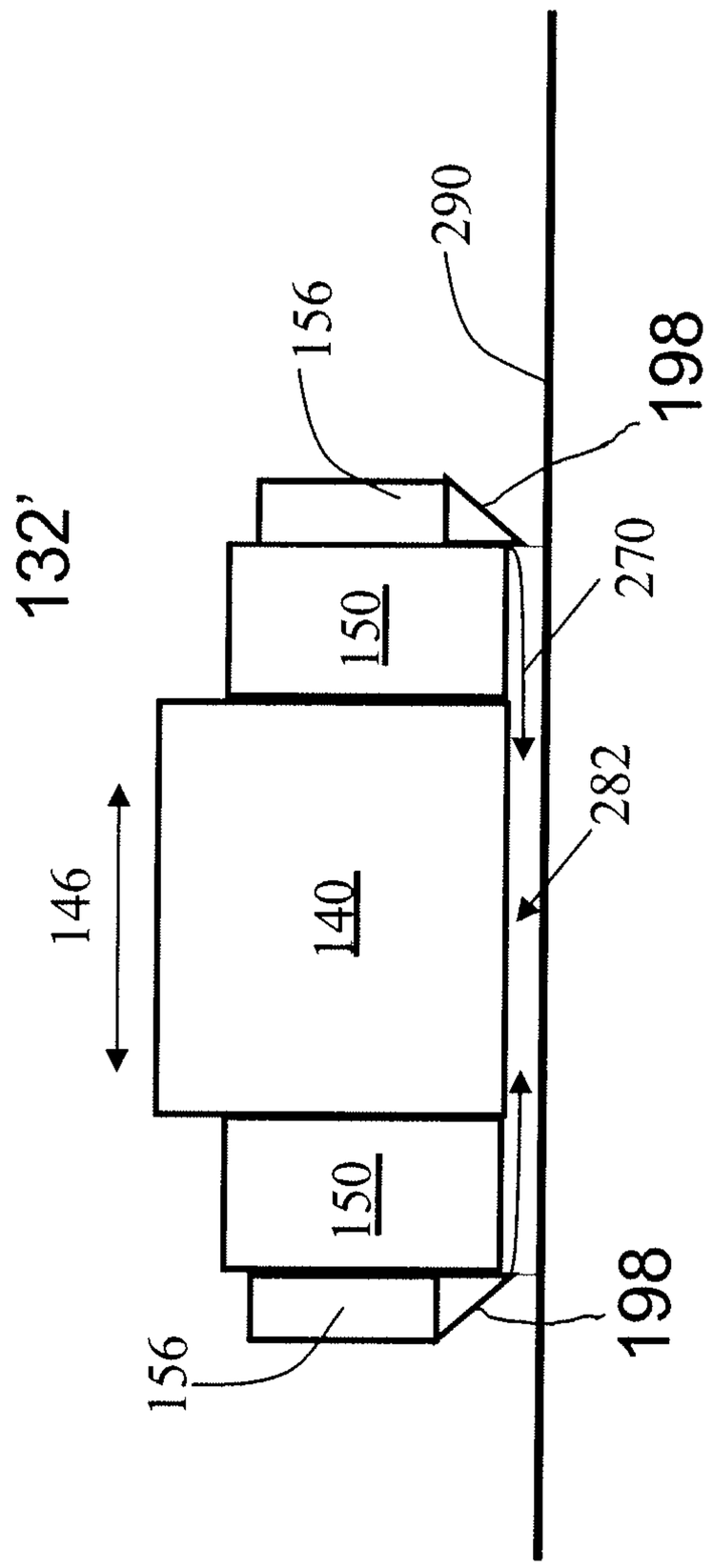


FIG. 7

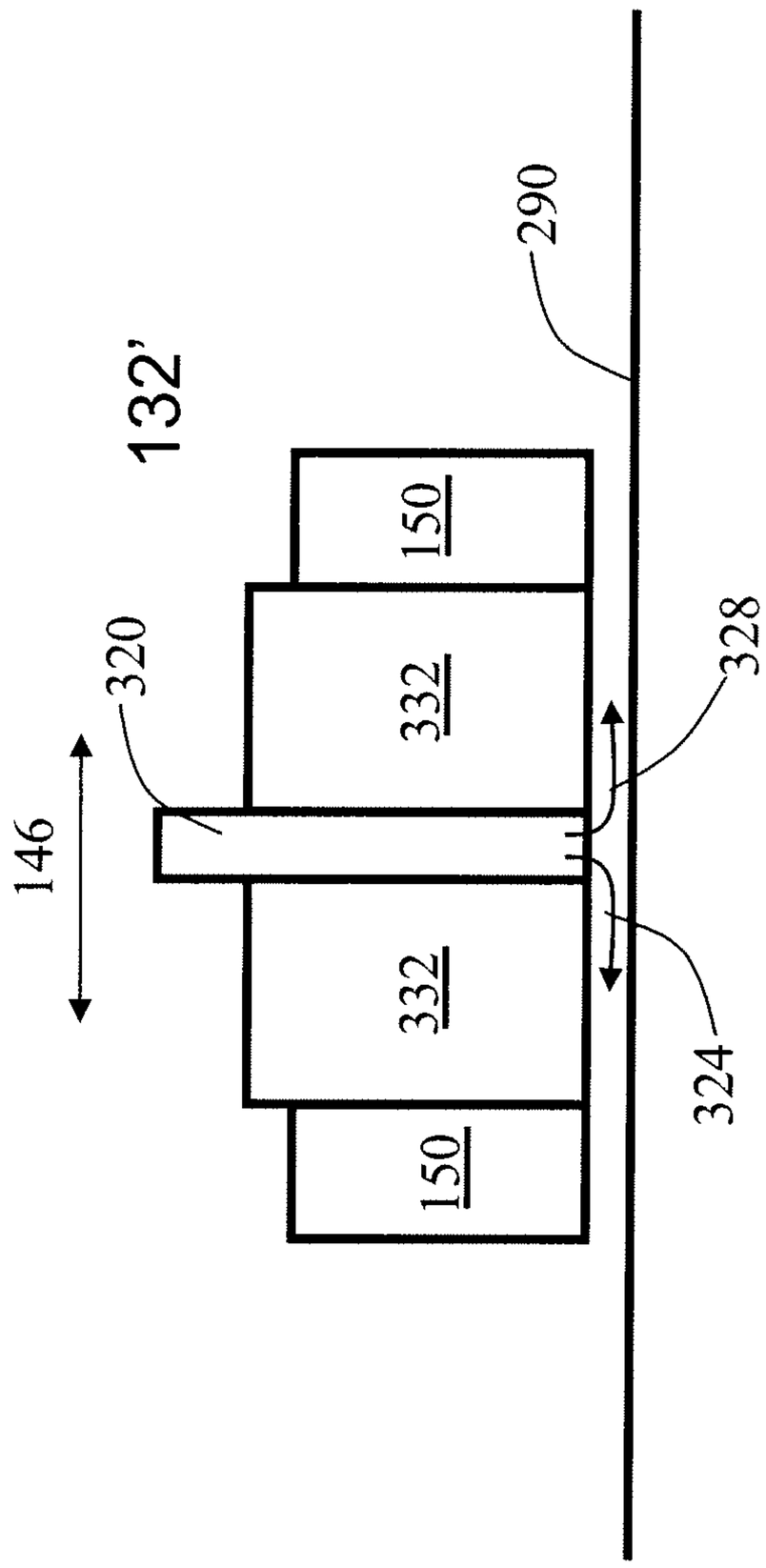


FIG. 8

PRINTING OR COATING APPARATUS AND METHOD

This application claims the benefit of U.S. provisional application Ser. Nos. 61/028,541, filed Feb. 14, 2008 and 61/032,094 filed Feb. 28, 2008. The entire contents of the aforementioned applications are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a method of, and apparatus for, printing on or coating a substrate. An embodiment of the invention relates to a printing apparatus or method for use with UV curable inks. Another embodiment relates to an apparatus or method for applying a UV curable coating to a substrate.

BACKGROUND

Inkjet printing is widely used for printing of billboards, banners and point of sale displays. The ink-jet printing process involves manipulation of drops of ink ejected from an orifice or a number of orifices of a print head onto an adjacent print substrate. Paper, vinyl, textiles, fabrics, and others are examples of print substrates. Relative movement between the substrate and the print head enables substrate coverage and image creation. A number of platens forming so-called substrate feed path carries out substrate transportation. Alternatively, the substrate may be located on a moving support usually termed flat bed support and moved together with the support. The print head typically reciprocates over the recording substrate ejecting ink droplets forming a section of an image or a swath at each path. After each reciprocating movement or pass, the substrate is further transported to a position where the next section of a desired image may be printed on it.

Printed ink should be dried or cured. Curable inks are more popular since they generate a light and waterproof image characterized by vivid colors. Curing radiation sources, such as UV lamps, may be static illuminating the whole width of printed image or associated with the print head and move with it. Ink curing requires large amounts of UV radiation and accordingly powerful UV sources are used to cure ink. There is a growing demand for faster printers printing on a variety of substrates including heat sensitive substrates. There is however a limit to the power and size of UV lamps that could be produced.

Instead of UV lamps, LEDs which emit UV radiation may be used. However an LED typically has a lower power output than a UV lamp.

In order to enable faster printing with UV curable inks it is necessary either to reduce the curing UV power or provide a more sensitive ink. Ink that is more sensitive has shorter shelf time, more toxic and more expensive. There is a need to provide a method of printing with UV curable ink free of the above drawbacks. There is a similar need associated with coating apparatus which uses a UV curable coating.

The apparatus and the method are particularly pointed out and distinctly claimed in the concluding portion of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

for a better understanding of the present invention reference will now be made by way of example to the accompanying drawings in which:

FIG. **1**A is a schematic illustration of an embodiment of a roll-to-roll inkjet printer operating with UV curable inks;

FIG. **1**B is a schematic illustration of an embodiment of a flat bed ink jet printer operating with UV curable inks;

FIGS. **2**A and **2**B are schematic illustrations of embodiments of a UV lamp based curing energy source of the printer of FIG. **1**;

FIGS. **3**A through **3**D are schematic illustrations of some exemplary embodiments of a LED based curing energy source of the printer of FIG. **1**;

FIGS. **4A1** and **4A2** are elevational and plan views respectively of an arrangement of a gas dispenser and a UV source;

FIGS. **4B1** and **4B2** are elevational and plan views respectively of another arrangement of a gas dispenser and a UV source;

FIG. **5** is a schematic illustration of a further exemplary embodiment of a printer with a UV source coupled with an inert gas source;

FIG. **6** is a schematic illustration of yet another exemplary embodiment of a printer with a UV source coupled with an inert gas source;

FIG. **7** is a schematic illustration of an alternative carriage which may be used in the embodiments of FIGS. **1**A and **1**B; and

FIG. **8** is a schematic illustration of another alternative carriage which may be used in the embodiments of FIGS. **1**A and **1**B.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Reference is made to FIG. **1**A, which is a schematic illustration of an inkjet printer operating with UV curable inks. Printer **100** is a wide format printer printing on a wide flexible substrate. Printer **100** may be of any known type such as for example, a roll-to-roll printer **104** that typically pulls a flexible printing substrate **108** from a supply roll **112** over a substrate support area to a receiving roll (not shown). A drive is provided for moving the substrate. In this example the drive rotates the axle of at least the receiving roll. The substrate is pulled over the printing area **114** in the direction indicated by the arrow **118**.

FIG. **1**B is a schematic illustration of flat bed inkjet printer **120** operating with UV curable inks. Printer **120** is a wide format printer **120** printing on a wide rigid substrate **124**. The rigid substrate **124** is supported by a table or bed **128** of the printer and travels with it. The substrate **124** is supported by a table **128** which is reciprocal in the direction **118**.

In both FIG. **1**A and FIG. **1**B, a carriage **132** is supported by a support structure **134** over the path of movement of the substrate **108** or **124**. The carriage **132** is reciprocal in a direction **146** transverse to the direction **118** of movement of the substrate. In this example the directions **118** and **146** are orthogonal. These two orthogonal movements allow ink droplet deposition at every location of the substrate.

The carriage **132** carries at least one inkjet print head **140** for depositing ink droplets on the substrate, at least one UV source **150** and at least one gas dispenser **156**. As shown schematically in FIG. **1**B, the, or each, gas dispenser **156** is connected to a gas supply **136** by a gas supply pipe **138**. The gas supply **136** is operable to supply to the dispenser(s) inert gas or gas which is at least depleted of oxygen. The dispenser is arranged to provide a layer of gas between the substrate and the area of substrate illuminated by the UV source. The layer of gas is at least depleted of oxygen.

The gas dispenser(s) and the UV source(s) may be in a permanently fixed position(s) relative to the carriage. Alter-

natively the positions of the gas dispenser(s) and UV source(s) may be adjustable allowing for adjustment to the distance between carriage and UV source(s) and gas dispenser(s) and/or between the UV source(s) and gas dispenser(s).

In alternative embodiments, the substrate may be static and the carriage may move in two orthogonal directions. Examples of printers which have such carriages are the HP 6500 available from the Hewlett Packard Company and the Espedio printer commercially available from Nur Macroprinters, Lod, Israel.

The carriage **132** of the printer of FIG. **1**A or **1**B has two UV sources **150**, two inert gas dispensers **156**, and a single print head **140**. The print head, gas dispensers and UV sources are aligned in the direction **146** of reciprocation of the carriage. The print head **140** is between one pair made up of a UV source **150**A and 1 and a gas dispenser **156**A and another pair made up of a gas dispenser **156**B and a UV source **150**B. When the carriage moves rightwards the print head **140** deposits ink and the UV source **150**B cures the deposited ink. When the carriage moves leftwards the print head **140** deposits ink and the UV source **150**A cures the deposited ink.

The UV source(s) **150** may each be a UV lamp with hot or cold mirror or a one-dimensional, two-dimensional array, or a three dimensional array of LEDs with suitable wavelength and one or more radiation directing and concentrating elements.

The gas supply **136** may supply to the gas dispenser(s) **156** an inert gas or a gas with low oxygen concentration. For example the gas may be nitrogen.

FIGS. **2**A and B are schematic illustrations of exemplary embodiments of a UV lamp based curing energy source useful in the printers of FIGS. **1**A and **1**B. In the embodiment of FIG. **2**A, the curing energy source is a UV lamp based source **164**. Source **164** may include in addition to lamp **168** a radiation concentrating and directing element such as a reflector **172**, directing and concentrating UV radiation to a printed section of substrate **108** or **124** to cure ink droplets on the substrate. In another 1 embodiment shown in FIG. **2**B, a mirror **178** is mounted at a proper angle to deflect UV radiation produced by lamp **168** to a printed section **176** (See, e.g., FIG. **3**D) of substrate **108** or **124**. The flexibility in arrangement of different UV source elements enables proper source construction. An optional protective transparent cover **180** preventing ink mist deposition on UV lamp **168** may be attached to restrict access to the lamp. In one embodiment, lamp reflector **172** may be a hot mirror reflecting infra red (IR) energy and heating up substrate. In another embodiment, where the printing takes place on heat sensitive substrates, lamp reflector **172** may be a cold mirror reflecting UV energy only and transmitting IR energy such that it does not heat the substrate **108** or **124**. In an alternative embodiment, mirror **178** may be a cold or hot mirror. In an yet another alternative embodiment, the protective cover **180** may be oriented and coated by proper coating to act as a cold or hot mirror/filter.

FIGS. **3**A to D are schematic illustrations of some exemplary embodiments of an LED based curing energy source **184** which may be used as the UV source(s) **150** in the printer of FIG. **1**A or FIG. **1**B. Source **184** may include in addition to a one dimensional (FIG. **3**A) or two dimensional (FIG. **3**B) or three dimensional (FIG. **3**C) array of LEDs **190**. One or more cylindrical lenses **194** (FIG. **3**D) may be provided for directing and concentrating UV radiation onto the substrate. A protective transparent cover **196** may be used to prevent deposition of ink mist on the lenses and LEDs.

The directing and concentrating element(s) **194**, **172**, may concentrate the UV radiation into a narrow band **192** of about 500 micron to about 10 mm wide on the substrate **108**, **124**. Such a band corresponds to the width of a swath of print deposited by the print head. Alternatively, the lenses **190** or other suitable lenses of the mirrors **172** may be arranged to provide a flood illumination covering a larger area of the substrate.

FIGS. **4A1**, A**2**, B**1** and B**2** are schematic illustrations of exemplary embodiments of gas dispensers useful as the dispensers **156** of FIG. **1**A or FIG. **1**B. In each Figure the dispenser **156** comprises a supply pipe **138** connected to a nozzle **198**. The nozzle directs the gas to the curing area only. The nozzle **198** acts as a flow director spreading gas flow **202** into a layer having at least the width of a section of the illuminated by the UV radiation. In one embodiment, shown in FIGS. **4A1** and **4A2**, gas flow **202** is spread by the nozzle **198** over a relatively large surface matching an area **200** illuminated by a UV source **150** and printed swath **204**. The nozzle may be arranged to limit any lateral gas spread. In another embodiment, shown in FIGS. **4B1** and **4B2**, inert gas flow **202** is concentrated by the nozzle **198** in a narrow strip type layer **206** matching the width of the band **192** illuminated by UV radiation provided in this example by an LED array **184** focused by concentrating and directing element **194**. The width **208** of strip **206** may be in the range from about 500 micron to 10 mm. In an embodiment the nozzle has a narrow slit with a width in the range about 0.5 mm to about 3 mm and the swath of print has a width equal to or less than the width of the slit.

FIG. **5** is a schematic illustration of another embodiment of a printing or coating apparatus. The apparatus comprises a printing or coating station at which a device **234** prints on a substrate **232** or applies a coating to the substrate as the substrate moves in the direction indicated by the arrow **118**. The printing or coating device **234** may be any known means such as a coating roller, a sprayer, a static wide array of inkjet print heads. The apparatus further comprises a curing station downstream of the coating station. In this example the curing station comprises a carriage **226**, supported by a carriage support structure **134'**, and which is arranged to reciprocate in a direction **146** transverse to the direction **118** of movement of the substrate. The carriage **226** carries at least one UV source **228** and at least one gas dispenser **230** for dispensing inert gas. The example shown in FIG. **5** comprises two UV sources, one each side of a gas dispenser **230**. The UV source(s) and the gas dispenser(s) cure print or a coating applied at the printing or coating station. Numeral **236** marks a coated but un-cured section of the substrate **232** upstream of the curing station, and numeral **238** marks a coated and cured section of the substrate **232** downstream of the curing station.

The apparatus of FIG. **5** may be used to pre-treat a substrate by applying a cured coating to it before printing takes place on the coated substrate. The printing may be done by a printer as shown in FIG. **1**A or B as described hereinabove.

FIG. **6** is a schematic illustration of another exemplary embodiment of printing or coating apparatus. The apparatus comprises a printing or coating station at which a device **234** prints on a substrate **232** with UV curable ink or applies a UV curable coating to the substrate as the substrate moves in the direction indicated by the arrow **118**. The printing or coating device **234** may be any known means for example a coating roller, a sprayer, or a static wide array of inkjet print heads. The apparatus further comprises a curing station downstream of the coating station. The curing station comprises a UV source **240** coupled with an inert gas dispenser **250**. The UV source and the gas dispenser cure print or a coating applied at the printing or coating station. The UV source **240** has a length, in the direction transverse to the direction **118**, equal to or greater than the width of the section **236** of the substrate

232 which is coated by or printed with a UV curable coating or ink. The UV source may be an assembly of lamps or an array of LEDs. Inert gas dispensed by the dispenser **250**. The dispenser in this example is upstream of the UV source. The dispenser has a length, in the direction transverse to the direction **118**, equal to or greater than the width of the section **236** of the substrate **232** which is coated by or printed with a UV curable coating or ink. The dispenser **250** concentrates gas flow **254** into a narrow strip **258** extending across the width of the substrate **232** reducing the power of the UV source required for curing of the coating, or supporting an increase in coating and curing speed. Numeral **236** denotes the coated but un-cured section of the substrate **232** upstream of the curing station, and numeral **238** denotes a coated and cured section of the substrate **232** downstream of the curing station.

FIG. **7** schematically illustrates a modification **132'** of the carriage **132** of the printer **100** or **120** of FIG. **1**A or **1**B. The carriage carries a print head **140** placed between two UV sources **150**, and two gas dispensers **156**, the print head **140** and UV sources **150** being between the dispensers **156**. The dispensers have nozzles **198** directed inwards to produce a layer of oxygen depleted gas under the carriage **132'**. In this example the dispensers introduce inert gas **270** under the print head **140** and the UV sources **150** generating one continuous oxygen depleted layer **282** which is shown in FIG. **7** over the substrate **290**. Layer **282** reduces if not eliminates contact of the ink with oxygen and reduces the UV power required for ink curing.

FIG. **8** is a schematic illustration of another example of a carriage **132'** useful in the printer **100** or **120** of FIG. **1**A or **1**B. The carriage is arranged to reciprocate in the direction **146**. It carries two UV sources **150** spaced apart by two print heads **332** between which is a gas dispenser **320**. In this example printing and ink curing take place in a continuous oxygen depleted layer. Gas, for example Nitrogen, is supplied through the dispenser **320** towards substrate **290**. The gas spreads in directions indicated by arrows **324** and **328** and fills the space beneath print heads **332** and UV sources **150** generating a continuous oxygen depleted layer. The dispenser in this example is a duct **320**.

The method of printing with printer **100** of FIG. **1**A of printer **120** of FIG. **1**B will be explained now. Printer **100** prints with, for example, UV curable ink such as HP UV **100** Supreme or UV **200** Supreme. Carriage **132** with print head **140** reciprocates over substrate **108** or **124** and deposits a swath **204** of ink droplets in an image wise manner. Inert gas is supplied by dispensers **156** to generate an oxygen-depleted layer over the ink droplets deposited on substrate **108** or **124**. The oxygen depleted layer over the ink reduces, or may prevent ink-oxygen inhibiting curing of the ink and may reduce by about ten times the UV power required to cure the printed ink droplets. This increase of sensitivity of the uncured ink layer allows significant reduction of the UV power required for ink curing. It allows reduction in the UV lamp or LED power and/or allows an increase in printing speed. Movement of substrate and/or print head allows deposition of ink droplets on any section of substrate to form an image of a desired size in a desired position.

The above-disclosed UV curing method and UV source and gas dispensing arrangements supporting low power UV curing may be used on a regular offset press with an inkjet print head or an array of print heads to cure varnish deposited by inkjet print heads.

Reduction in the power of the curing radiation sources allows increase in the printer throughput. It also allows use of lower power UV sources further reducing the cost of the printer and increasing printing profitability.

Providing a reciprocal carriage which carries at least one print head, at least one UV source and at least one gas dispenser in close proximity provides a compact apparatus in which the generation of the oxygen depleted layer takes place almost simultaneously with the operation of the UV source and allows the gas to be dispensed accurately under the UV source and print head. Providing two UV sources and dispensers with a print head between them allows efficient operation when the carriage reciprocates.

The invention claimed is:

1. An inkjet printing apparatus to print on a substrate, the apparatus comprising:

a first support which is a substrate support; and

a second support supporting at least one inkjet printing head, at least one UV source of ultraviolet radiation, and at least one gas dispenser, the at least one inkjet printing head coupled to the at least one UV source, or the at least one gas dispenser, or both, wherein the UV source comprises a UV lamp and a reflector to concentrate and direct the ultraviolet radiation from the UV source onto the substrate,

the second support being moveable relative to the substrate supported by the first support to deposit ink on the substrate and to cure the deposited ink,

the at least one gas dispenser having a nozzle to direct a flow of oxygen-depleted gas under the at least one UV source and to provide a layer of oxygen-depleted gas between the UV source and the deposited ink.

2. Apparatus according to claim **1**, wherein the first support is fixed and comprises a drive operable to move the substrate, relative to the first support, in a first direction, and the second support is a carriage for reciprocal movement in a second direction orthogonal to the said first direction.

3. Apparatus according to claim **2**, wherein the at least one UV source comprises first and second UV sources, wherein the at least one inkjet printing head is positioned between the first and second UV sources, the inkjet printing print head and the first and second UV sources being aligned in the said second direction, and wherein the at least one gas dispenser comprises first and second gas dispensers, the inkjet printing head and the first and second UV sources disposed between the first and second gas dispensers, the first and second gas dispensers arranged to provide a continuous layer of oxygen-depleted gas under the at least one inkjet printing head and the first and second UV sources and between the carriage and the substrate.

4. The apparatus of claim **3** wherein the first and second gas dispensers each has a bent-tipped nozzle, wherein bent tips of the nozzles are to face toward each other to provide the layer of oxygen-depleted gas.

5. Apparatus according to claim **1**, wherein positions of the UV source and the gas dispenser are adjustable relative to the inkjet printing head.

6. Apparatus according to claim **1**, wherein the reflector comprises a mirror and the apparatus further comprising a transparent cover positioned to prevent ink from being deposited on the UV lamp.

7. Apparatus according to claim **1**, wherein the nozzle has an angled end and is to direct the flow of oxygen-depleted gas to a portion of the substrate illuminated by the UV source, a width of the layer of oxygen-depleted gas to correspond with a width of UV source illumination.

8. A method of inkjet printing on a substrate, the method using the apparatus of claim **1**, the method comprising:

during a movement of the second support relative to the substrate, using the inkjet printing head to deposit ink on the substrate and curing the deposited ink using the UV

source while the inkjet printing head prints on the substrate and the gas dispenser dispenses gas to provide the layer of oxygen-depleted gas between the UV source and the deposited ink.

9. An inkjet printing apparatus to print on a substrate, the apparatus comprising:

a first support which is a substrate support; and

a second support supporting at least one inkjet printing head, at least one UV source of ultraviolet radiation, and at least one gas dispenser, the at least one inkjet printing head coupled to the at least one UV source, or the at least one gas dispenser, or both,

the second support being moveable relative to the substrate supported by the first support to deposit ink on the substrate and to cure the deposited ink,

the at least one gas dispenser having a nozzle to direct a flow of oxygen-depleted gas under the at least one UV source and to provide a layer of oxygen-depleted gas between the UV source and the deposited ink, wherein the nozzle has an angled end and is to direct the flow of oxygen-depleted gas to a portion of the substrate illuminated by the UV source, a width of the layer of oxygen-depleted gas to correspond with a width of UV source illumination, wherein the nozzle has a width in the range of from 500 microns to 10 mm.

10. Apparatus for applying material to a substrate, the apparatus comprising:

a drive operable to move the substrate in a first direction;

a coating station to apply a curable material to the substrate as the substrate moves in the first direction; and

a carriage carrying at least two UV sources of ultraviolet radiation to cure the curable material, and at least one gas dispenser coupled to the UV sources to provide a layer of gas, which is at least depleted of oxygen, between the UV sources and the substrate, one of the UV sources coupled to one side of the gas dispenser and the other of the UV sources coupled to an opposing side of the gas dispenser,

the carriage spaced apart from the coating station in the first direction and being reciprocal in a second direction orthogonal to the said first direction.

11. The apparatus of claim **10** wherein the coating station is to apply a coating to the substrate, and the UV sources are to cure the coating, the apparatus further comprising a print head to deposit ink on the cured coating.

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